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(54) **A temperature responsive display device**

(57) A temperature responsive display device 1 e.g. in the form of a fever scope, comprises a light absorbing layer and arranged, e.g. printed, in front of the latter, at least two thermochromic liquid crystal compositions (3*a* -*b* , 4*a* -*b* , 5) having different clearing points which mask the backing layer, at least one of the clearing points being chosen to be in the normal operating temperture of the display device. In use, the display visible is provided by the contrast between any thermochromic liquid crystal composition 8 which has not been rendered transparent and the light absorbing backing layer visible directly or through portions 7 of the overlying liquid crystal compositions which have been rendered transparent. As shown for use on a forehead, three different thermochromic liquid crystal layers clear at 34.5°C, 36°C and 45°C over a black backing layer. Above 34.5°C 'N' clears to show black on a green area 8. At 36°C,'F' and area 11 remain green while area 10 is black. At 45°C, area 14 clears to leave 'F+' green. In a room thermometer, Fig 5 (not shown) the black backing layer is uncovered gradually in thirteen steps to represent a rising black line from a bulb area.

FIG. 2

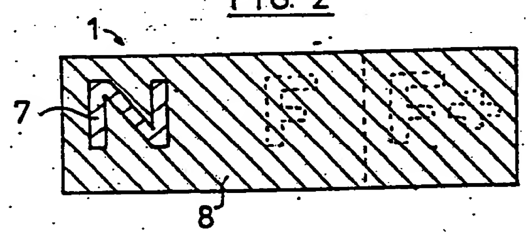


FIG. 3

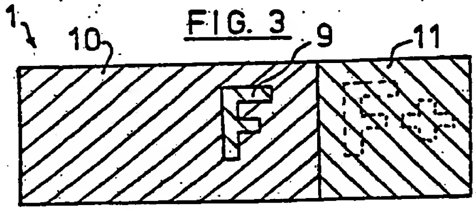


FIG. 4

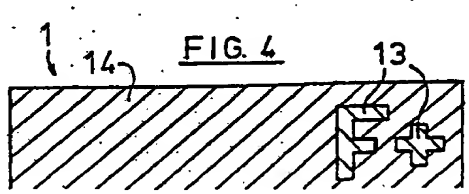


FIG. 2

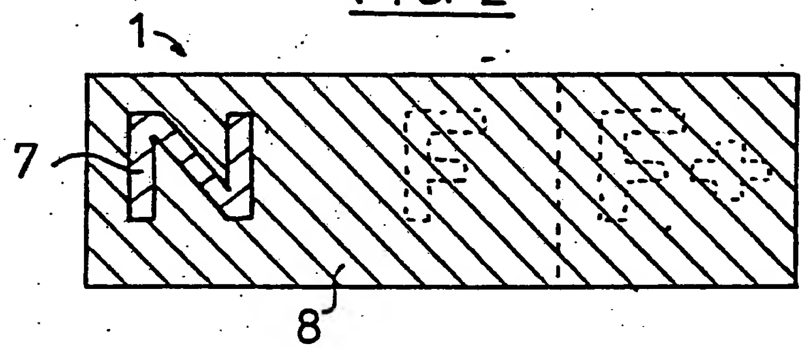


FIG. 3

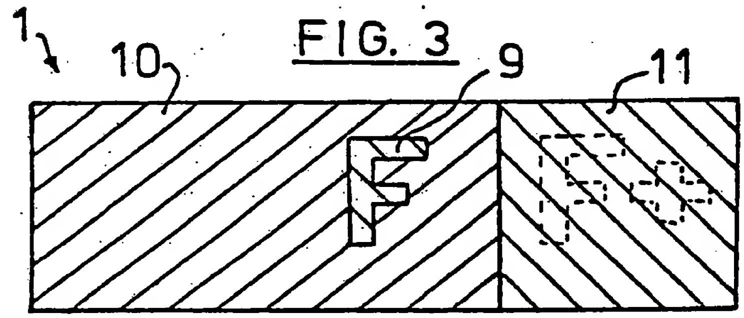
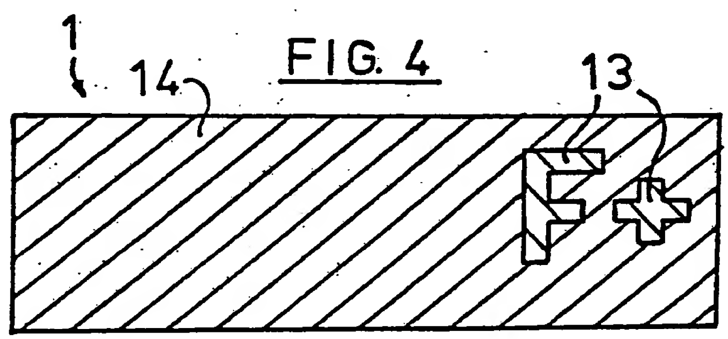


FIG. 4



A temperature responsive display device

This invention relates to a temperature responsive display device comprising at least two thermochromic liquid crystal compositions.

Thermochromic liquid crystal compositions are well known and heretofore have been employed in a wide range of temperature sensing applications, e.g. in thermometry as digital thermometers or fever scopes or in thermography. These known applications make use of the fact that a thermochromic liquid crystal composition can exist in a cholesteric phase in which the composition has temperature dependent optical properties.

Typically a thermochromic liquid crystal composition can exist in a smectic phase or the cholesteric phase between its crystal state and its isotropic state. When in the smectic phase, a thermochromic liquid crystal composition is virtually transparent and reflects virtually no light. On heating the composition after transition from the smectic phase to the cholesteric phase the thermochromic liquid crystal composition displays thermochromism, undergoing a "colour play", e.g. from "start of red" to "start of blue" in the visible spectrum. The temperature over which this colour play takes place is known as the colour play temperature range. As the thermochromic liquid crystal composition is heated further it eventually undergoes a transition from the cholesteric phase to its isotropic state in which state the composition is substantially transparent and reflects virtually no light. The temperature at which the liquid crystal composition undergoes the transition from a liquid crystal phase, e.g. the cholesteric phase, to the isotropic state is known as the "clearing point".

Other types of thermochromic liquid crystal compositions are known which have a low temperature dependence

backing layer is placed against a user's forehead and the first and/or second thermochromic liquid crystal compositions display thermochromism in dependence on the temperature sensed which is visible through the permanently opaque masking layer. Depending on the colour of the "N" and/or "F" visible through the masking layer, a representation of the user's forehead temperature (typically 2-2.5°C less than the user's internal body temperature) is obtained. In this known device the colour play properties of the thermochromic liquid crystal compositions are employed in conjunction with a permanently opaque, windowed masking layer in front of these compositions.

The present invention seeks to provide an alternative form of temperature responsive display device incorporating at least two thermochromic liquid crystal compositions having different clearing points.

According to the present invention, there is provided a temperature responsive display device comprising a light absorbing backing layer and, arranged, e.g. printed, in front of the latter, at least two thermochromic liquid crystal compositions having different clearing points which mask the backing layer, at least one of the clearing points being selected to be in the normal operating temperature range of the display device, whereby, when the display device is subjected to incident light and the temperature of the display device is elevated from a temperature below the lowest clearing point to a temperature above the highest clearing point, an increasing proportion of the backing layer is revealed as the various clearing points are passed through, the display visible at any stage of the temperature elevation being provided by the contrast between any thermochromic liquid crystal composition which has not been rendered transparent and the light absorbing backing layer visible directly or through portions of the overlying liquid crystal compo-

material, which may be convenient types of plastics material, will typically have a thickness of about 750 μm.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figures 1A to 1D are schematic representations of four different layers printed onto a flexible, transparent, front carrier sheet of a temperature responsive display device according to the invention in the form of a fever scope;

Figures 2 to 4 are schematic plans of various representations illustrated by the fever scope of Figures 1A to 1D at different temperatures; and

Figure 5 is a view of a thermometer type device illustrating a different application of a temperature responsive device according to the invention.

Figures 1A to 1D show the various stages in the manufacture of a fever scope 1, each figure illustrating the different layers which are printed onto the inner surface of a thin, flexible, transparent upper or outer layer 2, e.g. a sheet of PVC or other plastics material. This outer layer 2 may be gloss or matt surfaced and is conveniently surface modified to eliminate static and to enable specially developed ink systems to key directly onto the modified surface during printing, e.g. using a web offset lithographic process. Such surface modified PVC film is known in the printing art.

Firstly any graphics and/or written matter (not shown) and intended to be viewed through the upper or outer layer 2 is printed onto the inner surface of the outer layer 2 by a conventional printing process, e.g.

surface area of the layer 2 which already has the thermochromic liquid crystal compositions printed thereon.

After the printing operations, a backing sheet (not shown), e.g. of plastics material, is adhered to the printed layer 2 so as to cover the light absorbing backing layer and sandwich the liquid crystal compositions between the backing sheet and the outer layer 2. This backing sheet and the outer layer 2 typically each have high thermal inertia and a thickness of about 750 μm so as to provide the fever scope 1 with a degee of "memory".

When the fever scope 1 is viewed from the front it will be appreciated that the backing sheet forms the back of the fever scope and the layer 2 forms the front of the fever scope. When viewed from the front, the light absorbing backing layer is masked by the regions 3a, 3b, 4a, 4b and 5 over its entire area apart from the unmasked area provided by the window 5a.

The thermochromic liquid crystal compositions are in the form of printing inks, in particular the thermochromic liquid crystal compositions being microencapsulated as is well known in the art. The microcapsules have a diameter of less than 20 μm, more prepreferably have a diameter of less than 20 μm, more preferably a diameter of from 10 - 15 μm, so that the printed regions 3 - 5 can be printed in thin layers, typically 20 μm thick, by known printing techniques, e.g. by a web offset lithographic process. The liquid crystal inks may be printed directly onto the layer 2. Alternatively a "tie coat" may be printed onto the layer 2 before the liquid crystal inks are printed thereon to improve the adhesion of the printing inks to the layer 2.

The three thermochromic liquid crystal compositions are characterised in that they possess different clearing

crystal composition typically has a clearing point of 34.5°C, the second thermochromic liquid crystal composition typically has a clearing point of 36°C and the first thermochromic liquid crystal composition typically has a clearing point of 45°C. The fever scope is intended for measuring forehead temperature (which is generally from 2-2.5°C lower than the corresponding internal body temperature). Forehead temperatures below 34.5°C are considered to be normal ("N") whereas forehead temperatures above 34.5°C suggest that the user has a fever ("F"). Forehead temepratures in excess of 36°C suggest that the user has a very high temperature ("F+").

In use of the fever scope 1, the user's forehead temperature is taken by placing the fever scope 1 against the forehead for approximately 30 seconds with the backing sheet in contact with the forehead and the transparent upper or outer layer 2 facing outwards. Whilst the fever scope 1 is against the forehead, the three thermochromic liquid crystal compositions are heated to the temperature of the forehead and any of three conditions will be displayed. If the forehead temperature is below 34.5°C, regions 3<u>a</u>, 3<u>b</u>, 4<u>a</u>, 4<u>b</u> and 5 will all display the same colour since the three liquid crystal compositions are all at temperatures below their respective clearing points. In the case where the liquid crystal compositions display a light green colour when at temperatures below their clearing point and the light absorbing backing layer is black, a black letter "N" (designated 7 in Figure 2) will be visible from the front through the window 5<u>a</u> of the region 5, the rest of the display showing a light green colouration (designated 8 in Figure 2). If the forehead temperature is above 34.5°C but below 36°C, the region 5 of the third thermochromic crystal composition will be transparent since the clearing point of the third liquid cyrstal composition will have been exceeded. A light green letter "F" (designated 9 in

3a, 3b, 4a, 4b and 5 and the light absorbing backing layer have been printed directly onto the inner surface of the transparent front layer. It is possible, although less desirable, to print these layers in the reverse order onto a back carrier sheet. In this case, however, the front covering layer would have to be laminated onto the overprinted back carrier sheet using clear adhesiv or, alternatively, a clear lacquer applied in place of the front covering layer of sheet material. The various regions of thermochromic liquid crystal compositions applied over the backing layer would of course be mirror images of the regions shown in Figures 1A to 1C.

The techniques described herein with reference to the fever scope 1 can be applied to other temperature responsive display devices. For example an oral thermometer can be constructed in a similar manner, although in this case the backing layer or carrier would have a degree of rigidity and would have the form of a spatula for insertion into the mouth. The thermochromic liquid cyrstal compositions would only be provided to cover a relatively small area, e.g. 2 cm^2, at one end of the spatula like carrier, and the clearing points would be adjusted to measure internal body temperature instead of forehead temperature.

Another application is illustrated in Figure 5 which shows a thermometer 20, in the shape of a conventional mercury-type room thermometer, having a circular bulb portion 21, an elongate tube portion 22 and a rectangular carrier 23. The carrier 23 may be printed with a light absorbing layer 24, typically a black layer, over the entire bulb portion 21 and tube portion 22, the layer 24 then being overprinted with thirteen rectangular portions a - m of different thermochromic liquid crystal compositions which are finally covered with a transparent protective layer. Preferably, however, the various por-

colour, e.g. light green in appearance. Thus as ambient air temperature increases, successive regions <u>a</u> to <u>m</u> will be rendered transparent as their clearing points are exceeded, and a black line will move up the portion 22. With such a thermometer, it is preferable that the thermochromic liquid crystal compositions and/or the thermometer have little or no memory and that the temperature at which each composition reverts to a liquid crystal phase, e.g. a cholesteric phase, from its isotropic state is the same as its clearing point.

In other applications, a filter layer may be employed to enable different colours to be displayed or to obtain a better colour match between different thermochromic liquid crystal compositions.

According to another aspect of the present invention there is provided a temperature responsive display device for providing a display over a temperature display range, the display device comprising a light absorbing backing layer and, arranged, e.g. printed, in from of the backing layer, at least one thermochromic liquid crystal composition having a clearing point in said temperature display range, the or each thermochromic liquid crystal composition displaying, when subjected to incident white light, a given colour over a wide range of temperatures immediately below the or its clearing point, said displayed colour contrasting with the light absorbing backing layer, whereby when the display device is subjected to an elevated temperature, the or each liquid crystal composition masks the underlying light absorbing backing layer until the temperature of the or each composition reaches its clearing point.

each composition having a "memory" for a period of time after its temperature is lowered below its clearing point.

6. A display device according to claim 5, in which the said "memory" is provided by the addition of cholesteric additives to the thermochromic liquid crystal compositions.

7. A display device according to claim 5, in which the liquid crystal compositions are sandwiched betw n sheets of high thermal inertia material, the type and thickness of such thermal inertia material determining the particular "memory".

8. A temperature responsive display device constructed and arranged substantially as herein described with reference to, and as illustrated in, Figures 1A - 1D, 2, 3 and 4 or Figure 5 of the accompanying drawings.

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